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PB-265 566

Richmond Lake
Brown County
South Dakota

National Eutrophication Survey, Corvallis, Oreg

Prepared for

Corvallis Environmental Research Lab, Oreg

Jan 77

PB 265 566

U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

WORKING PAPER SERIES

REPORT
ON
RICHMOND LAKE
BROWN COUNTY
SOUTH DAKOTA
EPA REGION VIII
WORKING PAPER No. 621

CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY - CORVALLIS, OREGON
and
ENVIRONMENTAL MONITORING & SUPPORT LABORATORY - LAS VEGAS, NEVADA

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

G.P.O. 899-440

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Report on Richmond Lake, Brown County, South Dakota		5. REPORT DATE Prepared January 1977 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Anonymous (National Eutrophication Survey Staff)		8. PERFORMING ORGANIZATION REPORT NO. Working Paper #621
9. PERFORMING ORGANIZATION NAME AND ADDRESS National Eutrophication Survey U.S. Environmental Protection Agency 200 S. W. 35th St. Corvallis, Oregon 97330		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Office of Research and Development U.S. Environmental Protection Agency 401 M Street, S. W. Washington, DC 20460		13. TYPE OF REPORT AND PERIOD COVERED Final - 1974 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES
Prepared in cooperation with the U.S. Environmental Protection Agency, National Environmental Research Center, Las Vegas, Nevada 89114

16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
eutrophication lakes nutrients phosphorus nitrogen loading		05B 05C

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Release unlimited		40
	20. SECURITY CLASS *(This page)*	22. PRICE PC A03 MF A01

EPA Form 2220-1 (9-73)

REPORT
ON
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WITH THE COOPERATION OF THE

SOUTH DAKOTA DEPARTMENT OF ENVIRONMENTAL PROTECTION

AND THE

SOUTH DAKOTA NATIONAL GUARD

JANUARY, 1977

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the South Dakota Departments of Environmental Protection and Game, Fish and Parks for professional involvement, to the South Dakota National Guard for conducting the tributary sampling phase of the Survey, and to those wastewater treatment plant operators who voluntarily provided effluent samples.

Allyn Lockner, Secretary, and Blaine Barker and Duane Murphy, Department of Environmental Quality; Douglas Hansen, Department of Game, Fish and Parks; and James Hayden, Director, State Lakes Preservation Committee provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

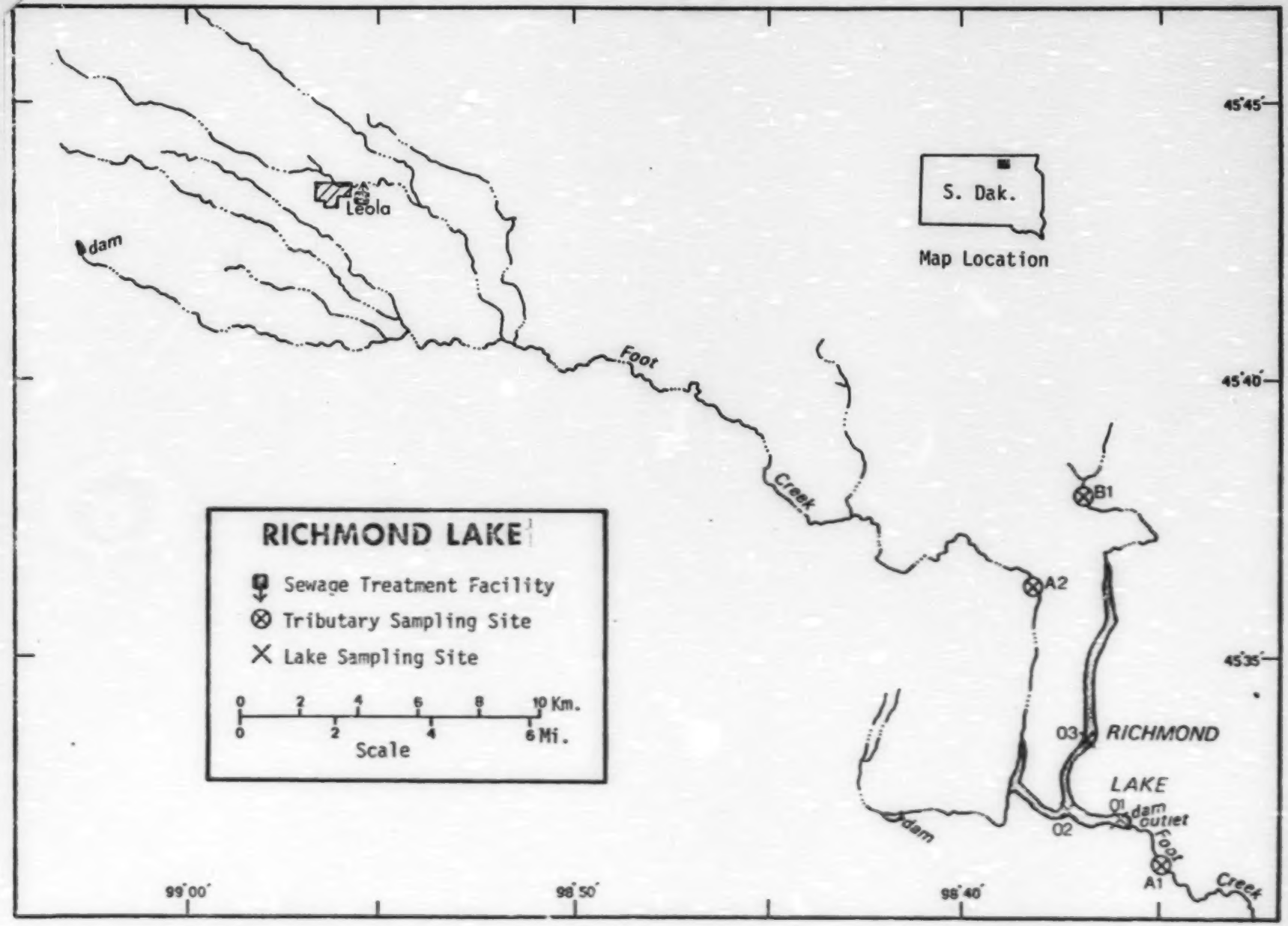
Major General Duane L. Corning, the Adjutant General of South Dakota, and Project Officer Colonel Robert D. Chalberg, who directed the volunteer efforts of the South Dakota National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF SOUTH DAKOTA

LAKE NAME	COUNTY
Albert	Kingsbury
Alvin	Lincoln
Angostura	Fall River
Brant	Lake
Byron	Beadle
Clear	Marshall
Clear	Minnehaha
Cochrane	Deuel
Cottonwood	Spink
Deerfield	Pennington
Enemy Swim	Day
Herman	Lake
John	Hamlin
Kampeska	Codington
Madison	Lake
Mitchell	Davidson
Norden	Hamlin
East Oakwood	Brookings
West Oakwood	Brookings
Pactola	Pennington
Pickerel	Day
Poinsett	Brookings, Lake
Red Iron South	Marshall
Richmond	Brown
Roy	Marshall
Sand	Brown
Sheridan	Pennington
Stockdale	Custer
East Vermillion	McCook
Wall	Minnehaha
Waubay	Day


RICHMOND LAKE
Sewage Treatment Facility
Tributary Sampling Site
Lake Sampling Site
0 2 4 6 8 10 Km.
0 2 4 6 Mi.
Scale
S. Dak.
Map Location
Leola
dam
Foot Creek
B1
A2
03
RICHMOND LAKE
01 dam outlet
02
dam
Foot Creek
A1
45°45'
45°40'
45°35'
99°00'
98°50'
98°40'

RICHMOND LAKE

STORET NO. 4624

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Richmond Lake is eutrophic. It ranked fifteenth in overall trophic quality when the 31 South Dakota lakes sampled in 1974 were compared using a combination of six water quality parameters*. Sixteen lakes had less median total phosphorus, 25 had less median dissolved orthophosphorus, 17 had less and two had the same median inorganic nitrogen, 12 had less mean chlorophyll a, and three had greater mean Secchi disc transparency.

Survey limnologists noted emergent vegetation along the shoreline at stations 1 and 3 in April and an algal bloom at all stations in September.

B. Rate-Limiting Nutrient:

The algal assay results indicate that Richmond Lake was limited by nitrogen at the time the sample was taken (09/18/74). The lake data indicate nitrogen limitation at all sampling stations and times.

C. Nutrient Controllability:

1. Point sources--Septic tanks serving lakeshore dwellings and two recreation areas contributed an estimated 8% of the total phosphorus load to Richmond Lake during the sampling year. However, a

* See Appendix A.

shoreline survey would have to be done to determine the actual significance of those sources.

In addition, the Leola municipal wastewater treatment pond discharges intermittently to Foot Creek about 45 kilometers upstream. The treatment facility was not sampled, and the significance of this source is not known. However, the phosphorus export rate of Foot Creek was very low (see below) which indicates the Leola discharge had a minimal impact during the sampling year.

The present phosphorus loading of 0.11 g/m^2/year is 1.8 times that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 11). In view of the extremely long mean hydraulic retention time (54 years), point-source phosphorus reduction alone probably would not result in a significant improvement in the trophic condition of the lake.

2. Non-point sources--Non-point sources contributed 92% of the total phosphorus input during the sampling year. Foot Creek contributed 42.7%, and the ungaged minor tributaries and immediate drainage contributed an estimated 33.3%.

The phosphorus export rate of Foot Creek was less than 0.5 kg/km^2/yr (see page 10).

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS†

A. Lake Morphometry††:

1. Surface area: 3.35 kilometers^2.
2. Mean depth: 4.6 meters.
3. Maximum depth: 8.8 meters.
4. Volume: 15.410 x 10^6 m^3.
5. Mean hydraulic retention time: 54 years (based on outflow).

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Foot Creek	373.0	0.009
Minor tributaries & immediate drainage -	74.3	0.007
Totals	447.3	0.016

2. Outlet -

Foot Creek	450.7**	0.009

C. Precipitation***:

1. Year of sampling: 27.4 centimeters.
2. Mean annual: 48.5 centimeters.

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† Table of metric conversions--Appendix B.
†† Murphey, 1974.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of lake.
*** See Working Paper No. 175.

III. LAKE WATER QUALITY SUMMARY

Richmond Lake was sampled three times during the open-water season of 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from two or more depths at three stations on the lake (see map, page v). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the last visit, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 6.1 meters at station 1, 3.4 meters at station 2, and 1.5 meters at station 3.

The sampling results are presented in full in Appendix D and are summarized in the following table.

A. SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR RICHMOND LAKE
STORET CODE 4624

PARAMETER	1ST SAMPLING (4/26/74) 3 SITES RANGE	MEAN	MEDIAN	2ND SAMPLING (7/10/74) 3 SITES RANGE	MEAN	MEDIAN	3RD SAMPLING (9/18/74) 3 SITES RANGE	MEAN	MEDIAN
TEMP (C)	9.8 - 11.5	10.7	10.7	23.0 - 25.6	24.4	24.3	15.6 - 17.0	16.2	16.1
DISS OXY (MG/L)	8.6 - 9.6	9.2	9.3	5.0 - 9.4	7.5	8.0	8.0 - 10.4	9.3	9.6
CNDCTVY (MCROMO)	696. - 723.	709.	710.	1006. - 1056.	1037.	1037.	894. - 922.	907.	906.
PH (STAND UNITS)	8.3 - 8.4	8.4	8.4	8.9 - 9.2	9.0	9.0	8.6 - 8.7	8.6	8.6
TOT ALK (MG/L)	236. - 400.	268.	248.	230. - 270.	255.	257.	325. - 450.	399.	398.
TOT P (MG/L)	0.120 - 0.153	0.138	0.138	0.153 - 0.208	0.184	0.187	0.229 - 0.361	0.280	0.272
ORTHO P (MG/L)	0.071 - 0.077	0.073	0.072	0.122 - 0.193	0.149	0.144	0.158 - 0.196	0.176	0.173
NO2+NO3 (MG/L)	0.050 - 0.080	0.062	0.060	0.020 - 0.100	0.059	0.045	0.020 - 0.030	0.021	0.020
AMMONIA (MG/L)	0.050 - 0.100	0.066	0.060	0.050 - 0.150	0.105	0.095	0.070 - 0.190	0.135	0.125
KJEL N (MG/L)	1.100 - 1.300	1.225	1.200	1.300 - 2.100	1.587	1.500	1.800 - 3.300	2.512	2.450
INORG N (MG/L)	0.100 - 0.170	0.129	0.120	0.070 - 0.250	0.164	0.185	0.090 - 0.210	0.156	0.150
TOTAL N (MG/L)	1.180 - 1.370	1.287	1.265	1.330 - 2.190	1.646	1.570	1.820 - 3.320	2.534	2.475
CHLRPYL A (UG/L)	6.1 - 7.8	7.0	7.2	2.7 - 20.7	10.5	8.2	24.5 - 52.9	37.8	36.1
SECCHI (METERS)	2.1 - 4.1	3.3	3.7	1.8 - 2.7	2.3	2.4	0.9 - 1.5	1.2	1.2

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
04/26/74	1. Chroomonas sp.	907
	2. Stephanodiscus sp.	272
	3. Cryptomonas sp.	45
	4. Schroederia sp.	45
	Total	1,269
07/10/74	1. Aphanizomenon sp.	1,618
	2. Chroomonas sp.	350
	3. Schroederia sp.	175
	4. Anabaena sp.	44
	Total	2,187
09/18/74	1. Aphanizomenon sp.	7,579
	2. Chroomonas sp.	234
	3. Oscillatoria sp.	94
	Total	7,907

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (µg/l)
04/26/74	1	7.2
	2	6.1
	3	7.8
07/10/74	1	2.7
	2	20.7
	3	8.2
09/18/74	1	52.9
	2	36.1
	3	24.5

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.070	0.180	8.6
0.050 P	0.120	0.180	8.5
0.050 P + 1.0 N	0.120	1.180	21.0
1.0 N	0.070	1.180	18.5

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity of Richmond Lake was high at the time the sample was collected (09/18/74). Also, the lack of growth response with the addition of phosphorus alone until nitrogen was also added indicates that the lake was limited by nitrogen at that time. Note that the addition of only nitrogen resulted in a yield significantly greater than that of the control.

The lake data also indicate nitrogen limitation; i.e., the mean inorganic nitrogen to orthophosphorus ratios were 2 to 1 or less at all sampling stations and times, and nitrogen limitation would be expected.

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the South Dakota National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v). Sampling was begun in October, 1974, and was completed in September, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the South Dakota District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were calculated using mean annual concentrations and mean annual flows. Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the mean concentrations in Foot Creek at station A-2 and the mean annual ZZ flow.

The Leola wastewater treatment plant was not sampled and since discharges to Foot Creek would be intermittent, estimates of nutrient loads were not made.

A. Waste Sources:

1. Known municipal* -

Name	Pop. Served	Treatment	Mean Flow (m^3/d)	Receiving Water
Leola	830	stab. pond	227.1	Foot Creek

2. Known industrial - None

* Anonymous, 1971.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/yr	% of total
a. Tributaries (non-point load) -		
Foot Creek	160	42.7
b. Minor tributaries & immediate drainage (non-point load) -	125	33.3
c. Known municipal STP's -		
Leola	?	-
d. Septic tanks* -	30	8.0
e. Known industrial - None	-	-
f. Direct precipitation** -	60	16.0
Total	375	100.0

2. Outputs -

Lake outlet - Foot Creek 30

3. Net annual P accumulation - 345 kg.

* Estimate based on 101 lakeshore dwellings and 2 parks; see Working Paper No. 175.
** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Foot Creek	740	12.2
b. Minor tributaries & immediate drainage (non-point load) -	575	9.5
c. Known municipal STP's -		
Leola	?	-
d. Septic tanks* -	1,145	18.8
e. Known industrial - None	-	-
f. Direct precipitation** -	3,615	59.5
Total	6,075	100.0

2. Outputs -

Lake outlet - Foot Creek 410

3. Net annual N accumulation - 5,665 kg.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Foot Creek	<0.5	2

E. Mean Nutrient Concentrations in Ungaged Stream:

Tributary	Mean Total P Conc. (mg/l)	Mean Total N Conc. (mg/l)
Unnamed Creek B-1	1.070	2.760

* Estimate based on 101 lakeshore dwellings and 2 parks; see Working Paper No. 175.
** See Working Paper No. 175.

F. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	0.11	0.10	1.8	1.7

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Richmond Lake:	
"Dangerous" (eutrophic loading)	0.06
"Permissible" (oligotrophic loading)	0.03

V. LITERATURE REVIEWED

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Murphey, Duane G., 1974. Personal communication (lake morphometry). SD Dept. of Env. Prot., Pierre.

Petrie, Lester R., and L. Rodney Larson, 1966 (?). Quality of water in selected lakes of eastern South Dakota. Rept. of Inv. #1, SD Water Res. Comm., Pierre.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
4601	LAKE ALBERT	0.321	0.170	48..111	106.289	9.200	0.019
4602	ALVIN LAKE	0.067	0.970	442.833	4.700	9.400	0.017
4603	ANGOSTURA RESERVOIR	0.019	0.160	423.333	3.717	13.000	0.005
4604	BRANT LAKE	0.194	0.130	432.833	34.150	11.800	0.113
4605	LAKE BYRON	0.443	0.370	488.333	149.350	9.000	0.146
4606	CLEAR LAKE	0.027	0.075	430.167	11.983	8.800	0.009
4607	CLEAR LAKE	1.400	0.270	495.333	691.000	7.000	0.468
4608	COCHRANE LAKE	0.037	0.150	446.000	15.683	15.000	0.008
4609	COTTONWOOD LAKE	0.685	0.265	490.333	112.017	8.600	0.417
4610	DEERFIELD RESERVOIR	0.033	0.080	303.333	3.650	15.000	0.022
4611	ENEMY SWIM LAKE	0.037	0.085	442.600	14.200	8.200	0.013
4612	LAKE HERMAN	0.340	0.155	485.000	58.733	8.600	0.174
4613	ST JOHN LAKE	0.348	0.080	489.400	120.880	9.800	0.025
4614	LAKE KAMPESKA	0.220	0.105	468.889	20.567	8.200	0.128
4615	MADISON LAKE	0.250	0.090	445.555	22.578	14.000	0.107
4616	LAKE MITCHELL	0.099	0.085	465.833	14.883	13.800	0.015
4617	LAKE NORDEN	0.256	0.165	488.667	46.800	10.000	0.050
4618	OAKWOOD LAKE EAST	0.146	0.175	487.000	113.600	10.000	0.009
4619	OAKWOOD LAKE WEST	0.181	0.135	485.833	159.667	9.600	0.021
4620	PACTOLA RESERVOIR	0.011	0.070	248.444	1.478	11.000	0.006
4621	PICKEREL LAKE	0.049	0.095	439.833	15.833	9.600	0.009
4622	LAKE POINSETT	0.115	0.315	468.444	40.211	10.000	0.023
4623	LAKE RED IRON SOUTH	0.042	0.110	430.333	6.883	7.600	0.010
4624	RICHMOND LAKE	0.187	0.150	410.000	18.467	10.000	0.144
4625	ROY LAKE	0.034	0.070	431.000	13.333	11.000	0.010
4626	SAND LAKE	0.489	0.110	471.800	65.790	12.800	0.288
4627	SHERIDAN LAKE	0.053	0.105	394.000	15.433	15.000	0.016
4628	STOCKADE LAKE	0.233	0.150	432.000	25.400	15.000	0.109

E DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
4629	LAKE VERMILLION	0.211	0.100	472.833	100.800	9.200	0.092
4630	WALL LAKE	0.194	0.160	441.667	55.267	7.400	0.076
4631	WAUBAY LAKE NORTH	0.098	0.145	469.555	127.033	11.400	0.023

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P	INDEX NO
4601	LAKE ALBERT	20 (6)	20 (6)	10 (3)	23 (7)	68 (20)	60 (18)	201
4602	ALVIN LAKE	67 (20)	0 (0)	57 (17)	90 (27)	63 (19)	63 (19)	340
4603	ANGOSTURA RESERVOIR	97 (29)	30 (9)	87 (26)	93 (28)	20 (6)	100 (30)	427
4604	BRANT LAKE	40 (12)	53 (16)	70 (21)	47 (14)	27 (8)	23 (7)	260
4605	LAKE BYRON	10 (3)	3 (1)	17 (5)	7 (2)	73 (22)	13 (4)	123
4606	CLEAR LAKE	93 (28)	93 (28)	83 (25)	83 (25)	77 (23)	90 (27)	519
4607	CLEAR LAKE	0 (0)	10 (3)	0 (0)	0 (0)	100 (30)	0 (0)	110
4608	COCHRANE LAKE	83 (25)	40 (11)	50 (15)	67 (20)	5 (0)	93 (28)	338
4609	COTTONWOOD LAKE	3 (1)	13 (4)	3 (1)	20 (6)	82 (24)	3 (1)	124
4610	DEERFIELD RESERVOIR	90 (27)	88 (26)	97 (29)	97 (29)	5 (0)	53 (16)	430
4611	ENEMY SWIM LAKE	80 (24)	82 (24)	60 (18)	77 (23)	88 (26)	73 (22)	460
4612	LAKE HERMAN	17 (5)	33 (10)	27 (8)	33 (10)	82 (24)	10 (3)	202
4613	ST JOHN LAKE	13 (4)	88 (26)	7 (2)	13 (4)	53 (16)	43 (13)	217
4614	LAKE KAMPESKA	33 (10)	65 (19)	40 (12)	57 (17)	88 (26)	20 (6)	303
4615	MADISON LAKE	27 (8)	77 (23)	53 (16)	53 (16)	13 (4)	30 (9)	253
4616	LAKE MITCHELL	60 (18)	82 (24)	47 (14)	73 (22)	17 (5)	70 (21)	349
4617	LAKE NORDEN	23 (7)	23 (7)	13 (4)	40 (12)	45 (12)	40 (12)	184
4618	OAKWOOD LAKE EAST	53 (16)	17 (5)	20 (6)	17 (5)	45 (12)	85 (25)	237
4619	OAKWOOD LAKE WEST	50 (15)	50 (15)	23 (7)	3 (1)	58 (17)	57 (17)	241
4620	PACTOLA RESERVOIR	100 (30)	98 (29)	100 (30)	100 (30)	35 (10)	97 (29)	530
4621	PICKEREL LAKE	73 (22)	73 (22)	67 (20)	63 (19)	58 (17)	85 (25)	419
4622	LAKE POINSETT	57 (17)	7 (2)	43 (13)	43 (13)	45 (12)	47 (14)	242
4623	LAKE RED IRON SOUTH	77 (23)	58 (17)	80 (24)	87 (26)	93 (28)	78 (23)	473
4624	RICHMOND LAKE	47 (14)	40 (11)	90 (27)	60 (18)	45 (12)	17 (5)	299
4625	ROY LAKE	87 (26)	98 (29)	77 (23)	80 (24)	35 (10)	78 (23)	455
4626	SAND LAKE	7 (2)	58 (17)	33 (10)	30 (9)	23 (7)	7 (2)	158
4627	SHERIDAN LAKE	70 (21)	65 (19)	93 (28)	70 (21)	5 (0)	67 (20)	370
4628	STOCKADE LAKE	30 (9)	40 (11)	73 (22)	50 (15)	5 (0)	27 (8)	225

ERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P	INDEX NO
4629	LAKE VERMILLION	37 (11)	70 (21)	30 (9)	27 (8)	68 (20)	33 (10)	265
4630	WALL LAKE	43 (13)	27 (8)	63 (19)	37 (11)	97 (29)	37 (11)	304
4631	WAUBAY LAKE NORTH	63 (19)	47 (14)	37 (11)	10 (3)	30 (9)	50 (15)	237

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
1	4620	PACTOLA RESERVOIR	530
2	4606	CLEAR LAKE	519
3	4623	LAKE RED IRON SOUTH	473
4	4611	ENEMY SWIM LAKE	460
5	4625	ROY LAKE	455
6	4610	DEERFIELD RESERVOIR	430
7	4603	ANGOSTURA RESERVOIR	427
8	4621	PICKEREL LAKE	419
9	4627	SHERIDAN LAKE	370
10	4616	LAKE MITCHELL	349
11	4602	ALVIN LAKE	340
12	4608	COCHRANE LAKE	338
13	4630	WALL LAKE	304
14	4614	LAKE KAMPESKA	303
15	4624	RICHMOND LAKE	299
16	4629	LAKE VERMILLION	265
17	4604	BRANT LAKE	260
18	4615	MADISON LAKE	253
19	4622	LAKE POINSETT	242
20	4619	OAKWOOD LAKE WEST	241
21	4631	WAUBAY LAKE NORTH	237
22	4618	OAKWOOD LAKE EAST	237
23	4628	STOCKADE LAKE	225
24	4613	ST JOHN LAKE	217
25	4612	LAKE HERMAN	202
26	4601	LAKE ALBERT	201
27	4617	LAKE NORDEN	184
	4626	SAND LAKE	158

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
29	4609	COTTONWOOD LAKE	124
30	4605	LAKE BYRON	123
31	4607	CLEAR LAKE	110

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR SOUTH DAKOTA 05/03/76

LAKE CODE 4624 RICHMOND

TOTAL DRAINAGE AREA OF LAKE(SQ KM) 450.7

NORMALIZED FLOWS(CMS)

TRIBUTARY	SUB-DRAINAGE AREA(SQ KM)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
4624A1	450.7	0.0	0.0	0.0	0.028	0.028	0.028	0.028	0.0	0.0	0.0	0.0	0.0	0.009
4624A2	373.0	0.0	0.0	0.0	0.028	0.028	0.028	0.028	0.0	0.0	0.0	0.0	0.0	0.009
4624ZZ	77.7	0.0	0.0	0.0	0.028	0.028	0.028	0.0	0.0	0.0	0.0	0.0	0.0	0.007

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 450.7
SUM OF SUB-DRAINAGE AREAS = 450.7

TOTAL FLOW IN = 0.20
TOTAL FLOW OUT = 0.11

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
4624A1	10	74	0.0	10	0.006				
	11	74	0.0	8	0.006				
	12	74	0.0	12	0.006				
	1	75	0.0	26	0.001				
	2	75	0.0	28	0.0				
	3	75	0.0	13	0.0				
	4	75	0.0	20	0.006				
	5	75	0.0	16	0.006				
	6	75	0.0						
	7	75	0.0	1	0.008	26	0.006		
	8	75	0.0	23	0.003				
	9	75	0.0	27	0.006				
4624A2	10	74	0.0	12	0.0				
	11	74	0.0	8	0.0				
	12	74	0.0	12	0.0				
	1	75	0.0	26	0.0				
	2	75	0.0	28	0.0				
	3	75	0.0	13	0.0				
	4	75	0.0	20	0.0				
	5	75	0.001	16	0.0				
	6	75	0.003						
	7	75	0.0	1	0.0	26	0.0		
	8	75	0.0	23	0.0				
	9	75	0.0	27	0.0				
4624ZZ	10	74	0.0						
	11	74	0.0						
	12	74	0.0						
	1	75	0.0						
	2	75	0.0						
	3	75	0.0						
	4	75	0.001						
	5	75	0.001						
	6	75	0.0						
	7	75	0.0						
	8	75	0.0						
	9	75	0.0						

APPENDIX D

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 76/05/03

462401
45 33 10.0 098 36 00.0 4
RICHMOND LAKE
46013 SOUTH DAKOTA

090691

11EPALES 2111202
0025 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/04/26	08	55 0000	10.3		144	701	8.30	278	0.050	1.300	0.070	0.072
	08	55 0005	10.2	8.6		701	8.40	240	0.050	1.300	0.050	0.075
	08	55 0020	9.8	9.6		696	8.30	236	0.060	1.200	0.060	0.077
74/07/10	10	25 0000	24.5	8.4	108	1037	9.00	230	0.100	2.100	0.090	0.193
	10	25 0005	24.4	8.4		1039	9.00	266	0.090	1.500	0.100	0.145
	10	25 0010	24.2	7.6		1036	9.00	246	0.080	1.300	0.030	0.146
	10	25 0017	23.0	5.0		1006	8.90	264	0.150	1.300	0.040	0.179
74/09/18	11	45 0000	16.2	10.0	60	906	8.58	405	0.190	2.900	0.020K	0.189
	11	45 0005	16.2	8.6		905	8.58	380	0.190	3.300	0.020	0.196
	11	45 0015	16.0			903	8.63	325	0.180	2.500	0.020	0.180

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/04/26	08	55 0000	0.124	7.2	
	08	55 0005	0.138		
	08	55 0020	0.133		1.0
74/07/10	10	25 0000	0.208	2.7	
	10	25 0005	0.191		
	10	25 0010	0.184		
	10	25 0017	0.207		
74/09/18	11	45 0000	0.309	52.9	
	11	45 0005	0.361		1.0
	11	45 0015	0.283		

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/03

462402
45 33 30.0 098 37 20.0 4
RICHMOND LAKE
46013 SOUTH DAKOTA
090691

11EPALES 2111202
0015 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/04/26	09 20	0000	11.5		162	723	8.40	238	0.060	1.200	0.060	0.072
	09 20	0005	11.5	9.2		719	8.40	252	0.070	1.100	0.080	0.074
	09 20	0011	10.7	9.4		710	8.40	256	0.050	1.300	0.050	0.073
74/07/10	10 55	0000	25.6	9.4	96	1056	9.20	254	0.050	1.600	0.020	0.122
	10 55	0007	25.1	8.4		1053	9.10	260	0.080	1.400	0.050	0.135
74/09/18	11 25	0000	17.0	10.4	48	922	8.64	390	0.070	3.100	0.020K	0.169
	11 25	0005	16.6	9.8		905	8.62	450	0.100	2.000	0.020	0.171
	11 25	0010	15.6	8.0		894	8.66	360	0.130	1.800	0.020	0.175

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/04/26	09 20	0000	0.120	6.1	
	09 20	0005	0.147		
	09 20	0011	0.153		
74/07/10	10 55	0000	0.191	20.7	
	10 55	0007	0.169		
74/09/18	11 25	0000	0.306	36.1	
	11 25	0005	0.235		
	11 25	0006			1.0
	11 25	0010	0.229		

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/03

462403
45 36 00.0 098 36 50.0 4
RICHMOND LAKE
46013 SOUTH DAKOTA

090691

11EPALES 2111202
0009 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/04/26	09 40	0000	10.9		84	710	8.35	244	0.100	1.200	0.070	0.071
	09 40	0002	10.9	9.4		710						
	09 40	0005	10.7	9.0		708	8.30	400	0.090	1.200	0.060	0.072
74/07/10	11 10	0000	24.3	6.6	72	1037	9.10	248	0.150	2.000	0.100	0.125
	11 10	0004	24.2	6.6		1033	9.00	270	0.140	1.500	0.040	0.144
74/09/18	11 10	0000	16.0	9.6	36	909	8.67	430	0.120	2.400	0.030	0.167
	11 10	0004	15.9	9.0		909	8.68	450	0.100	2.100	0.020	0.158

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/04/26	09 40	0000	0.138	7.8	
	09 40	0005	0.151		
74/07/10	11 10	0000	0.153	8.2	
	11 10	0004	0.171		
74/09/18	11 10	0000	0.262	24.5	
	11 10	0004	0.255		1.0

APPENDIX E

TRIBUTARY DATA

STORET RETRIEVAL DATE 76/05/04

462441
45 31 10.0 098 34 39.0 4
FOUT CREEK
46 7.5 RICHMOND
U/RICHMOND LAKE 090691
SEC NO BMD' 1 MI BELO RICHMOND LAKE DAM
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/12	09	35	0.008	0.900	0.020	0.005	0.030
74/11/08	13	45	0.008	1.500	0.055	0.055	0.065
74/12/12	12	05	0.008	1.300	0.015	0.020	0.040
75/04/20	13	10	0.190	1.250	0.185	0.110	0.150
75/05/16	15	10	0.010	1.980	0.060	0.095	0.158
75/07/01	19	45	0.015	1.750	0.065	0.150	0.200
75/07/26	14	45	0.005	1.450	0.055	0.160	0.210
75/08/23	14	30	0.015	1.630	0.050	0.085	0.100
75/09/27	16	30	0.015	0.980	0.020	0.005	0.050

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/04

462442
45 34 35.0 098 38 10.0 4
FOOT CREEK
46 7.5 RICHMOND SW
T/RICHMOND LAKE 130591
SEC RD BRDG 4.8 MI NW OF RICHMOND
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
75/04/20	13 30		0.390	1.800	0.205	0.270	0.320
75/05/16	15 40		0.015	2.300	0.057	0.250	0.340
75/07/01	18 00		0.015	1.800	0.195	0.950	0.960
75/07/26	15 10		0.025	4.100	0.045	0.200	0.670
75/08/23	15 30		0.050		0.034	1.250	

STORET RETRIEVAL DATE 76/05/04

462481
45 38 05.0 098 36 50.0 4
UNNAMED CREEK
46 7.5 RICHMOND NE
I/RICHMOND LAKE 090691
SEC RD BRDG 5.4 MI SW OF WEST PORT
11EPALES 211120
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
75/04/20	13 45		0.360	1.730	0.315	0.350	0.460
75/05/16	16 05		0.010	2.100	0.070	0.700	0.710
75/07/01	18 15		0.015	4.200	0.520	2.630	2.900
75/07/26	15 25		0.015	4.200	0.080	0.370	0.690
75/08/23	16 00		0.010	2.600	0.055	0.645	0.800
75/09/27	17 30		0.020	1.300	0.045	0.810	0.860